BEHAVIOR CLASSIFICATION, SECURITY, AND CONSENSUS IN SOCIETIES OF ROBOTS

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Introduction

We consider how very large numbers of heterogenous robots, differing in their bodies, sensing and intelligence, may be made to coexist, communicate, and compete fairly towards achieving their individual goals, i.e. to build a "society of robots". We introduce a formalism that allows a large variety of possible cooperative systems to be uniformly modeled and we discuss some characteristics that the rules defining acceptable social behaviors should possess. We consider threats that may be posed to such a society by the misbehaviors of some of its members, due either to faults or malice, and the possibility to detect and isolate them through cooperation of peers. We study the problem of classifying a set of robotic agents, based on their dynamics or the interaction protocols they obeys, as belonging to different "species". We finally study distributed algorithms that members of the society can use to reach a consensus on the environment and on the integrity of the peers, so as to improve the overall security of the society of robots.

Fig.1: A futuristic mall scenario.

Towards a Society of Robots

- Increasing need for applications in which heterogeneous robots will coexist and collaborate to achieve a common goal;
- for instance, we can imagine that in the future personal robots will go to shop for the family (Fig. 1);
- as for Human and animal societies, "sociality" in these artificial systems is based on the establishment of "rules of interaction" among the individuals of their societies themselves;
- the **Decentralization** is the key of achieving features such as *scalability*, *heterogeneity*, and *reconfigurability.*

Behavior Classification and Security

- "**Behavior-based**" societies of robots can be built by giving a set of rules that each agent should follow, which are only based on local information and communication between neighboring agents;
- The complexity need to represent such behaviors can be successfully captured by hybrid models, where the continuous--time dynamics describes the physical motion of each agent, and the event--based one describes the sequence of interactions with its neighbors;
- At the base of interaction is the ability of each individual (agent) to distinguish or ***classify*** the other neighboring members (agents) of the society as belonging to the same group or species (Fig. 2-3);
- ***Robot heterogeneity*** can be used to model the existence of malfunctioning agents or of ***intruders***, which are maliciously reprogrammed to implement a different behavior than the nominal one.

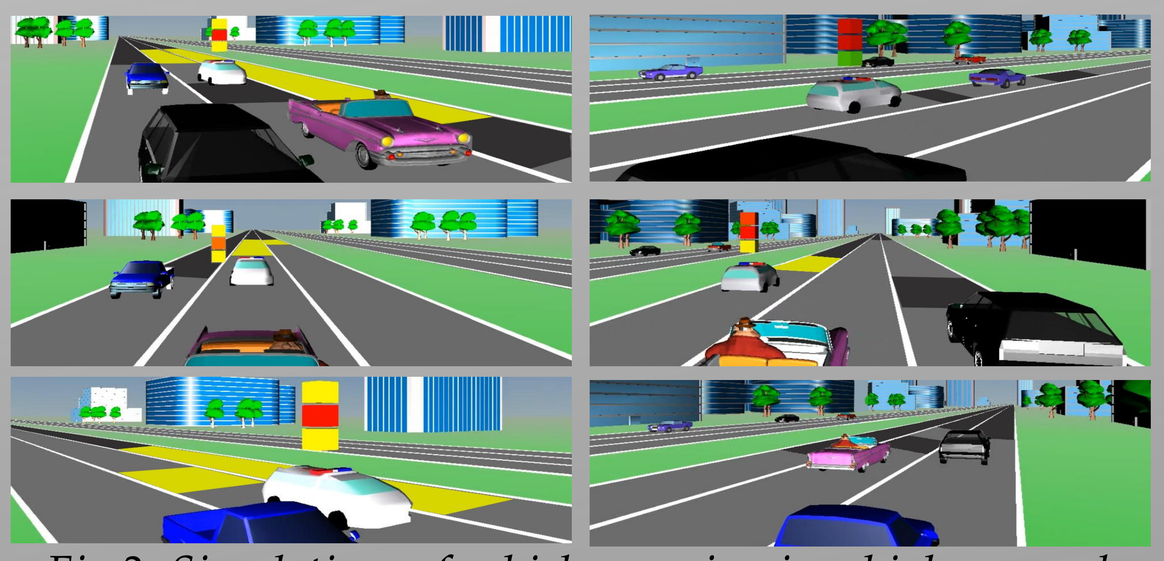

Fig.2: Simulations of vehicles moving in a highway and following different traffic rules.

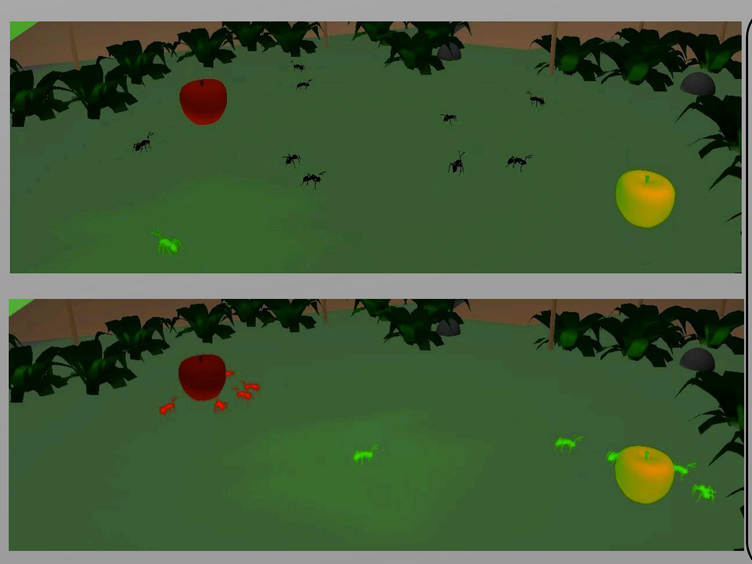

Fig.3: Two different ant species

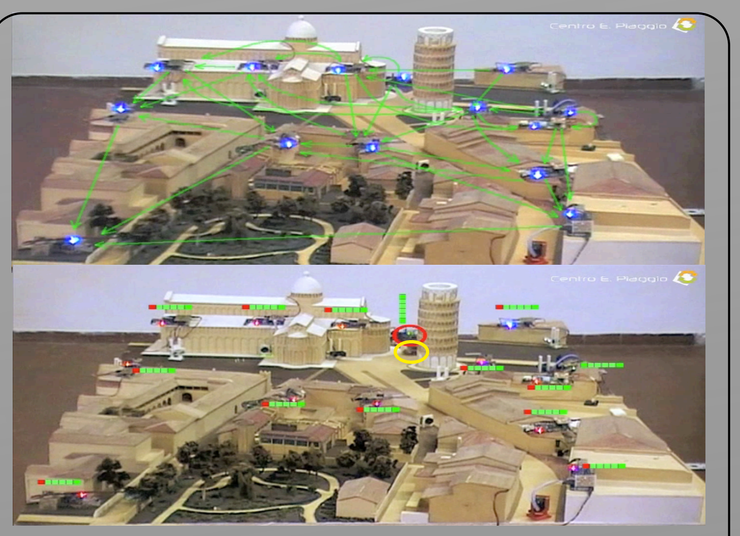

Fig.4: Intrusion Detection

Global Awareness and Consensus

- Many of the problems on distributed robotics require that agents consents on information represented by data consisting of scalars (such as a temperature or the concentration of a chemical) or vectors (e.g. positions or velocities);
- However, the complexity of the problems emerging in society of robots entails defining consensus algorithms on different representations of the state of information;
- In these systems, it is necessary to build a unique global view of the information, via only one-hop information exchange interactions, also tolerating possible failures (Fig. 4).

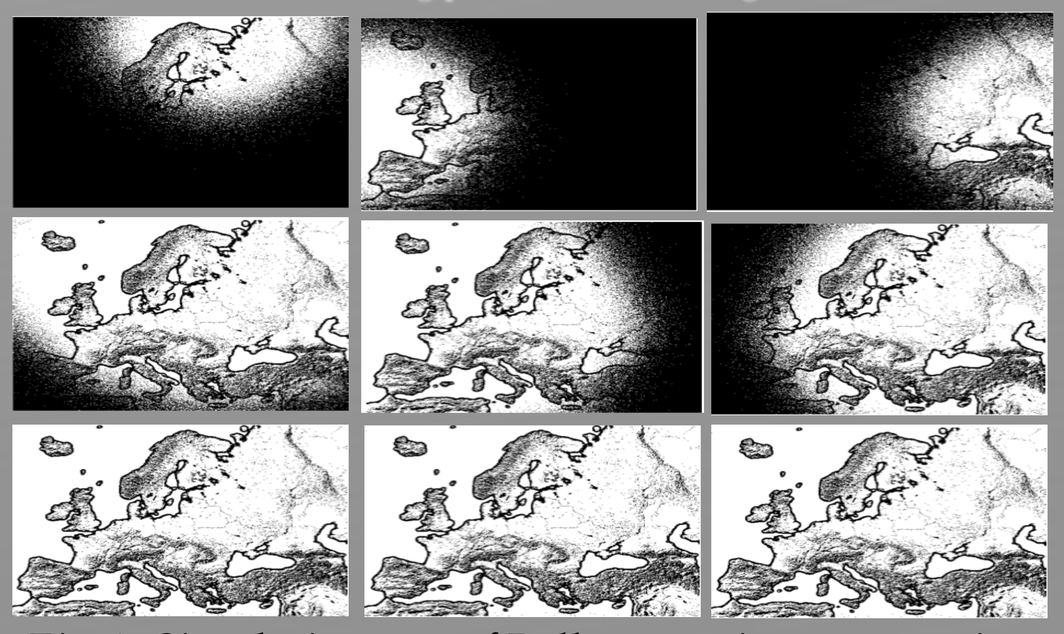

Fig.4: Simulation run of Balloon stations consenting on a global view of the European continent contours.

Conclusion

We have considered some of the problems that will be encountered in the construction of large systems of autonomous and heterogeneous robots. The role of hybrid automata descriptions in providing verifiable safety properties, and in building general distributed intrusion detection and classification systems for increasing the security and global awareness of these systems has been shown. The method has also been applied to allow members of a society to classify other individuals based on their behaviors in case a model for such behavior is available. If this is not the case, a much harder and very interesting problem arises which requires construction of a model for a behavior that is observed in individuals of the society.

Acknowledgment

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References

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